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CONSEQUENCES OF US NAVY DIVING MISHAPS: AIR EMBOLISM
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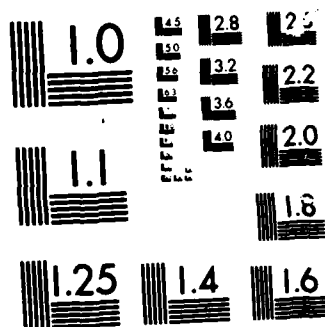
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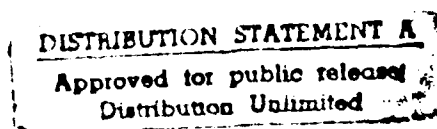
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CONSEQUENCES OF U.S. NAVY DIVING MISHAPS: AIR EMBOLISM AND BAROTRAUMA

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REPORT NO. 85-45



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CONSEQUENCES OF U.S. NAVY DIVING MISHAPS:
AIR EMBOLISM AND BAROTRAUMA

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SUMMARY

Problem

Pulmonary barotrauma and air embolism have been reported to be second only to drowning as the leading causes of death among sport and scuba divers. Barotraumas and air embolisms accounted for 21.9% and 3.6%, respectively, of all U.S. Navy diving mishaps recorded from 1968 through 1981. Research should be conducted to identify the subsequent health consequences of these conditions among U.S. Navy divers.

Objectives

The purpose of this study was to examine the short- and long-term health effects of an air embolism or barotrauma and to determine whether or not these consequences could be attributed to diving accidents.

Approach

The sample consisted of 165 U.S. Navy male enlisted divers and diving officers, 27 of whom had experienced an air embolism and 138 a barotrauma from January 1968 through December 1979. Identification of 163 of these divers was made by selecting all records that indicated the type of accident as an air embolism or barotrauma on the Diving Log-Accident/Injury Report file which was obtained from the Naval Safety Center in Norfolk. The other two divers had no diving accident data but had a diving-related hospitalization or physical evaluation board. Frequencies of diagnoses were compiled into a tabular chronology for all physical disabilities, medical boards, and hospital admissions that occurred prior to, in conjunction with, and subsequent to the mishap.

Results

Of the 27 divers who suffered an air embolism, 11 divers were hospitalized immediately and three divers died as a result of the diving mishap. Only four divers were subsequently hospitalized, all for reasons unrelated to diving or the air embolism. The two cases of prior admissions also were not associated with the air embolism or a subsequent hospitalization. None of the divers in the air embolism sample was separated or retired with a physical disability.

Of the 138 divers who experienced a barotrauma diving accident, three were hospitalized immediately and five others were admitted during the first year after the mishap. Three of these hospitalizations were for ear and hearing problems, one of which resulted in a physical disability for deafness. No other hospital admissions or physical disabilities were attributable to the barotrauma mishap. Nine divers had a hospitalization for diseases of the respiratory system prior to the diving mishap, but these events probably were unrelated to the subsequent diving mishap because they occurred at least 10 months before the barotrauma incident. The frequencies of diagnoses for the other hospitalizations that occurred prior to the barotrauma were very low.

Conclusions

Three divers' deaths were caused by an air embolism. For the other divers in the air embolism sample, no subsequent ill health problems were attributable to the air embolism. In the barotrauma sample, the incidence of ear and hearing problems for three divers, one of whom was separated for deafness, suggested that the barotrauma was the genesis of these conditions. No prior health condition was shown to be associated with the incidence of either an air embolism or barotrauma.

Recommendations

The loss of three lives to air embolism and the incidence of ear and hearing problems in three divers emphasized the need to further promote adherence to the safety procedures established by the Navy diving community.

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Consequences of U.S. Navy Diving Mishaps:

Air Embolism and Barotrauma

In a recently published article on U.S. Navy diving accidents, the most frequently reported accident was decompression sickness (DCS), which accounted for 41.1% of all mishaps, followed by barotrauma with 21.9% (1). Incidence of the potentially fatal disorder of air embolism was relatively low at 3.6%. Although research on these diving disorders has been quite extensive, few studies have been reported on the subsequent effects or consequences of these conditions on the diver's health. Research reported by Rivera (2) and Hoiberg (3) were but two studies that endeavored to assess the health status of divers subsequent to a DCS incident. Hoiberg determined that divers who experienced DCS tended to be at increased risk for two clusters of disorders, including symptoms and headache and disorders of the arteries and veins. The incidence of these conditions, however, was shown to be very low.

The purpose of this study was to examine the short- and long-term health effects of an air embolism or barotrauma and to determine whether or not these consequences could be attributed to diving accidents. The subsequent medical events or health consequences included hospital admissions, medical boards, physical evaluation boards, deaths, and physical disability separations and retirements.

Air embolism and barotrauma are caused by exposure to the effects of pressure on the diver in an underwater environment. Changes in pressure and gas volume have to be accommodated in the cavities of the diver's body. If the pressure of air or gas in a cavity becomes different from the surrounding tissue, one of the following conditions could occur: aural barotrauma, gastrointestinal barotrauma, pulmonary barotrauma, sinus barotrauma, and air embolism.

Of these conditions, pulmonary barotrauma and air embolism have been reported to be second only to drowning as the leading causes of death among sport and scuba divers (4,5). Pulmonary barotrauma occurs primarily as a result of coming to the surface while holding the breath. During such an ascent, water pressure on the body decreases, the air in the lung expands, the diaphragm and chest walls stretch, the lung tissue stretches and tears, allowing air to flow into the pulmonary circulation or intrapleural space (4). This process can lead to air embolism--and to death. Of all deaths attributed to diving, 20% result because of air embolism (6).

METHOD

The sample for this study consisted of 165 U.S. Navy male enlisted divers and diving officers, 27 of whom had experienced an air embolism and 138 a barotrauma from January 1968 through December 1979. No women divers were included because no woman had a recorded incident for these reasons. Identification of all but two of the 165 divers was made by selecting all records that indicated the type of accident as an air embolism or barotrauma on the Diving Log-Accident/Injury Report (OPNAV 9940/1) file which was provided to the Naval Health Research Center, San Diego, by the Naval Safety Center in Norfolk. Data extracted from this file included the type of accident reported, date of occurrence, accident outcome, most significant sign or symptom, organ system involved, treatment outcome, number of days lost from duty for treatment, last year of diving, and number of dives. The other two divers had no diving accident data but had a diving-related hospitalization or physical evaluation board.

Information on subsequent medical events and career status was obtained from three data bases maintained at the Naval Health Research Center: the Naval Medical Inpatient file, Naval Enlisted Service History file, and Naval Officer Career History file. Data extracted from the medical inpatient file for the January 1968 through December 1979 time period were diagnoses and dates for all hospitalizations, medical boards, and physical evaluation boards as well as dates and underlying causes of death. Service and career history data included dates and reasons for separation or retirement from active duty.

Frequency distributions were obtained to identify divers in both samples who were separated from active duty and/or who had been hospitalized or reviewed by a medical board subsequent to the diving accident. For those who had a recorded medical event, each of the diagnoses and the number of days, months, and years after the mishap date were listed in a tabular chronology. These entries included the diagnoses for all physical disabilities, medical boards, and hospital admissions that occurred in conjunction with the mishap and during each subsequent year after the accident. Prior diagnoses also were tabulated in order to determine if there was a specific disease or cluster of disorders associated with an increased risk of experiencing an accident. The diagnostic nomenclature used was the Eighth Revision of the International Classification of Diseases Adapted for Use in the United States (ICDA-8).

RESULTS

Air embolism

In examining the diving accident data for the 27 divers identified as having had an air embolism mishap, the following treatment outcomes were recorded: two divers died as a direct result of the air embolism accident, three divers experienced a recurrence, two divers reported substantial relief, 18 divers responded as having experienced complete relief, and two divers had no diving accident data (one of whom only had a physical evaluation board that identified an air embolism as the cause of his death). Table 1 is a presentation of the subsequent events for these 27 divers. Follow-up observations revealed that there was one additional death which occurred seven years subsequent to the initial diving mishap; no attribution to the air embolism incident could be inferred from the diver's record. None of the other 23 divers was separated or retired with a physical disability because of the air embolism.

Other follow-up information presented in Table 1 showed that the immediate health effects included hospitalization of 11 divers as a result of the diving accident. The diagnoses were air embolism (7 divers), dyspnea (1 diver), and decompression sickness (3 divers which also consisted of one with emphysema and air embolism as additional diagnoses and another with air embolism as a secondary diagnosis). Only two of these divers were subsequently hospitalized: one diver was hospitalized for alcoholism six years and two months after the mishap and the other had an admission for alcoholism and abdominal pain symptoms three and five years later, respectively, with a nondisability retirement to the fleet reserve at age 40. Other results identified a 35-year-old diver as being hospitalized for emphysema six months after the air embolism incident; another diver was hospitalized 40 months later for other diseases of the upper respiratory tract, followed three years later by a hospitalization for unspecified neoplasm of the larynx. The latter diver also had a prior hospitalization for synovitis. (The only other precursory disorder observed in this sample was an admission for tonsillitis.) The other 10 divers had no subsequent

TABLE 1

Subsequent Hospitalizations and Separations from Service
among U.S. Navy Divers Treated for Air Embolism ($n = 27$), 1968-79

Treatment Outcome:

Death--Immediate Hospitalization for Air Embolism (2 divers)

Recurrence--Death, unrelated to air embolism (7 yrs later) (1)

Immediate hospitalization for air embolism/released from active duty (1)

No hospitalizations/released from active duty (1)

Substantial relief--No hospitalizations/released from active duty (1)

No hospitalizations/remained on active duty at end of follow-up (1)

Complete relief--Immediate hospitalization for air embolism/subsequent hospitalization for alcoholism (6 yrs, 2 mos later)/remained on active duty (1)

Immediate hospitalization for air embolism/released from active duty (4)

Immediate hospitalization for decompression sickness and air embolism/remained on active duty (2)

Immediate hospitalization for decompression sickness/separated from active duty (5 yrs later) (1)

Immediate hospitalization for symptoms referable to the respiratory system (dyspnea)/remained on active duty (1)

Subsequent hospitalization for emphysema (6 mos later)/retired (4 yrs later) (1)

Subsequent hospitalizations for other diseases of upper respiratory tract (3 yrs, 4 mos later) and unspecified neoplasm of larynx (3 yrs later)/separated from active duty (1)

No hospitalizations/released or separated from active duty (5)

No hospitalizations/remained on active duty at end of follow-up (2)

No diving accident record--Death related to on-duty diving accident as recorded on physical evaluation board (1)

Immediate hospitalization for air embolism/subsequent hospitalizations for alcoholism (3 yrs later) and symptoms referable to the abdomen and lower gastrointestinal tract (abdominal pain) (5 yrs later)/retired (2 mos later) (1)

serious ill health effects as reflected by no records of hospital admissions, medical boards, physical evaluation boards, physical disabilities, or deaths.

Barotrauma

A total of 138 divers had a diving accident record identifying barotrauma as the type of accident experienced; the treatment outcome indicated complete relief for 85 divers and substantial relief for 53 individuals. The follow-up data are presented in Table 2. In compiling data on the subsequent medical events, no deaths were recorded and one diver was separated from active duty with a physical disability for deafness which occurred four months after the barotrauma incident. His diving accident record indicated that the treatment outcome was substantial relief and that he lost three days from duty for treatment.

Immediately after the barotrauma mishap, three divers were hospitalized for the following reasons: decompression sickness, observation, and vertigo. No subsequent adverse health consequences were recorded for these men. In addition to these three cases, five divers were hospitalized during the first year for transient situational disturbances (1 diver), displacement of the intervertebral disc (1 diver), and various combinations of hearing impairment, otitis media, otitis externa, and other diseases of the ear (3 divers). One of these five divers had a unique case history in that he had been hospitalized twice for diving-related injuries, experienced two barotraumas in May and August of 1976, and was hospitalized for transient situational disturbances in October 1976. His diving record revealed a history of more than 400

TABLE 2

Subsequent Hospitalizations and Separations from Service
among U.S. Navy Divers Treated for Barotrauma (n = 138), 1968-79

Treatment Outcome:

Substantial relief--Immediate hospitalization for certain symptoms of the nervous system (vertigo)/separated from active duty (1 diver)
Subsequent hospitalization for deafness (4 mos later)/separated with a physical disability for deafness (3 mos later) (1)
Subsequent hospitalization for otitis media, otitis externa, and other diseases of the ear and mastoid process (8 days later)/released from active duty (2 yrs, 4 mos later) (1)
Subsequent hospitalization for other diseases of the ear and mastoid process (3 mos later)/appointed to officer status (1)
No hospitalizations/released or separated from active duty (13)
No hospitalizations/remained on active duty at end of follow-up (36)

Complete relief--Immediate hospitalization for decompression sickness/ remained on active duty (1)
Immediate hospitalization for observation/remained on active duty (1)
Subsequent hospitalization for displacement of the intervertebral disc (7 mos later)/retired (2 yrs 6 mos later) (1)
Subsequent hospitalization for transient situational disturbances (2 mos later)/remained on active duty (1)
Subsequent hospitalization for alcoholism (3 yrs, 4 mos later)/retired (4 yrs later) (1)
Subsequent hospitalizations for symptoms of cardiovascular system (2 yrs later) and displacement of the intervertebral disc (1 yr, 4 mos later)/retired with a nondiving-related physical disability (1)
No hospitalizations/released or separated from active duty (50)
No hospitalizations/remained on active duty at end of follow-up (29)

dives, and he was listed as an active diver at the end of the follow-up period. The only long-term ill health consequences that might be associated with diving and possibly the barotrauma were one case of alcoholism and one diver who was hospitalized for displacement of the intervertebral disc. The latter diver recorded a total of 93 dives from 1968 through 1978 with a diving accident in 1968 (barotrauma) and a DCS incident in 1973. He retired with a physical disability two years after his last year of diving; his health record revealed no data indicating that the disability was diving related.

Other findings showed that 87 divers had records of no hospital admissions or board appearances either before or after the barotrauma. The remainder of the sample (41 divers) either had had a hospitalization prior to the barotrauma and/or the subsequent medical event was unrelated to diving (e.g., acute tonsillitis). The most frequently occurring precursory diseases included respiratory disorders for nine divers, diarrheal disease for four divers, and two each with other viral diseases, alcoholism, and other diseases of the blood.

DISCUSSION

Results of this study identified three deaths because of an air embolism and a physical disability separation from service for deafness among 165 U.S. Navy divers who experienced an air embolism or barotrauma diving accident during the time period from January 1968 through December 1979. In addition to the diver who was discharged for deafness, two other divers were hospitalized for ear and hearing problems. Neither diver had a subsequent adverse medical event nor physical disability. The incidence of these ear and hearing problems corresponded with findings reported by other researchers who concluded that hearing loss is of great concern to divers (7,8). The incidence of the barotrauma and the subsequent hospital admissions for ear and

hearing conditions in three divers suggested that the barotrauma was the genesis of these conditions.

Alcohol-related problems were observed for three divers; however, their hospitalizations for alcoholism occurred many years after the initial diving accident. Other subsequent medical events included two divers who were hospitalized for displacement of the intervertebral disc and two who appeared before a medical board for the same reason. No other disorder was shown to have a frequency of more than two hospitalizations.

While ear and hearing problems were disorders that could be attributed to a barotrauma, the serious health problems (i.e., ones requiring a hospitalization) that occurred prior to the diving accident seemed to have little, if any, impact as a precursory disease on the incidence of an air embolism or barotrauma. In particular, no relationship between the two prior hospital admissions and the subsequent air embolism could be established from an examination of the type of illness or proximity of events in time. For the barotrauma sample, on the other hand, the number of admissions for respiratory diseases was higher than that observed for any other major diagnostic category. In examining the time sequence of these events in relation to the diving accident, the most proximal admissions were 10 and 13 months, respectively, for pneumonia and hay fever. Because of the considerable duration of time between the prior hospital admissions and the diving accident, the observed respiratory conditions did not appear to increase the diver's susceptibility to experiencing a barotrauma.

When one considers the fact that Navy divers performed approximately 70,000 dives annually for the time period of this study, the incidence of 27 air embolisms and 138 barotraumas represented an extremely low diving accident rate for these conditions. After these accidents, 159 divers continued to serve on active duty, seemingly in excellent health. The loss of three lives to air embolism and the incidence of ear and hearing problems in three divers, however, emphasized the need to further promote adherence to the safety procedures established by the Navy diving community and to the medical standards developed for divers (9).

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